DRAFT TECHNICAL MEMORANDUM

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TO: Linda Meyer
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SUBJECT: Task 1, Deliverable 5A: Evaluation of Current Gas Monitoring Plan

The purpose of this Technical Memorandum is to document an analysis of the currently proposed post-closure monitoring plan and the action levels that trigger the extraction of phosphine gas from the closed RCRA ponds at the site.

1.0 BACKGROUND

1.1 September 2010/January 2011 – RCRA Pond UAO – SOW Task 1, Air Monitoring Plan – Part I and Part II

This FMC document, which does not reflect FMC's currently proposed post-closure monitoring plan, provides a plan for perimeter surface monitoring, site appurtenance monitoring, site boundary monitoring, and continuous pond perimeter monitoring. The perimeter surface monitoring outlined in the plan specifies monthly or quarterly monitoring of the pond surface with a Draeger Pac III instrument at approximately 1 to 2 inches above the ground surface. The action level for the perimeter surface monitoring is 0.05 ppmv (63 ug/m^3 at average ambient conditions of Pocatello, ID.) Exceeding the action level prompts additional investigation designed to identify the source of the release including monitoring the entire pond surface.

The site appurtenance monitoring includes leak detection monitoring (measured 1 to 2 inches from the appurtenance) and air monitoring (measured 12 inches from the appurtenance) with the Draeger Pac III instrument. The action levels for the monitoring are 0.05 ppmv and 1.0 ppmv (1,254 ug/m^3 at ambient conditions typical of Pocatello, ID.) The lower action level is used to control the frequency of the monitoring which for some ponds began at a monthly frequency and for others at a quarterly frequency. The plan provided for a reduction in monitoring frequency based on whether or not the 0.05 ppmv action level is exceeded after one year of monitoring. Exceeding the 1.0 ppmv action level triggers additional boundary and low-lying area monitoring.

The site boundary monitoring was discontinued on or about March 2011. The site boundary monitoring consisted of using the Draeger Pac III instrument to measure the ambient air every 4 hours at one of multiple fixed points on the fence surrounding the site. The monitoring program used an action level of 0.25 ppmv (314 ug/m^3 at ambient conditions typical of Pocatello, ID) as a trigger for additional off-site monitoring. The monitoring was reportedly discontinued because no measurements in excess of 0.00 ppmv were detected. (It should be noted that the Draeger Pac III with the XXS PH3 Sensor has a reported detection limit of 0.02 ppmv (25 ug/m^3).

The pond perimeter continuous monitoring occurs at fixed locations near the pond perimeter, again with the Draeger Pac III. The monitors log 1-minute average concentrations and the 8-hr Time Weighted Average (TWA) during the period of use. Additional fenceline monitoring is implemented if the continuous pond perimeter monitoring results in a single 1-minute average concentration that exceeds 1.0 ppmv (1,254 ug/m^3) during the 8-hr monitoring period, or the 8-hr TWA exceeds 0.3 ppmv (376 ug/m^3).

1.2 January 2012 – RCRA Pond Phosphine Assessment Study Report

The stated purpose of this FMC report was to:

1. demonstrate where and how frequently monitoring should be conducted at each of the RCRA ponds to protect human health and the environment;
2. determine the phosphine concentrations which if met or exceeded would trigger additional monitoring and phosphine gas extraction and treatment.

Cap perimeter surface scans and appurtenance monitoring was conducted either quarterly or annually. The document also discusses perimeter pipe monitoring for certain ponds that was not discussed in Section 1.1 above. The specific sampling and analysis discussed in this report consists of:

1. TMP sampling – PH3
2. Perimeter gas collection piping – PH3
3. Perimeter shallow soil gas sampling – PH3
4. Perimeter soil gas step-out sampling – PH3
5. Inside pond appurtenance sampling – PH3
6. Perimeter pipe - (HCN, H2S, HF)

The document appears to conclude that no additional soil gas, perimeter pipe, and TMP monitoring was required for Ponds 8S, 9E, Phase IV, 8E, and 17. This determination appears to be based on data collected for these ponds which showed a significant number of results reported as 0.00 ppmv. [Note: the Draeger Pac III monitor has a manufacturer reported detection limit of 0.02 ppmv (25 ug/m^3)]. Additional soil gas, perimeter pipe, and TMP monitoring was recommend for 18A, 16S, and 15S.

The report does not specifically address phosphine trigger concentrations except to note that such concentrations are expected to be greater than 1,700 ppmv in the perimeter pipe for some of the ponds. The report does compare some monitoring results to health and safety action levels like the permissible exposure limits (PEL) published by OSHA. The USEPA Region 10 industrial and residential screening air concentrations were not discussed.

1.3 July 16, 2012 – Framework for Post-Closure Phosphine Monitoring

This FMC document describes FMC's thinking at this point regarding its plans for post-closure monitoring. The document summarizes the historical monitoring data up to the date of the document and uses it to develop a conceptual long-term monitoring plan that FMC argues will provide a mechanism to identify phosphine releases before they occur, and provide phosphine gas trigger levels that start and stop the gas extraction systems. The monitoring plan is complicated and involves various increases in appurtenance and stand pipe monitoring frequency until phosphine concentrations reach certain levels, at which point gas extraction and treatment is started. The instrument upon which the monitoring is based is the Draeger Pac III. The proposed baseline appurtenance and stand pipe monitoring frequencies are as follows:

- Ponds 8S, 8E, 9E, Phase IV Ponds: Annual
- Ponds 16S, 18A, 17, and 15S: Quarterly

The appurtenance monitoring action levels which trigger a greater monitoring frequency are based on OSHA Permissible Exposure Limits (0.3 ppmv), OSHA Short-Term Exposure Limits (1 ppm), and the NIOSH IDLH (50 ppmv). There is also an "Outside Appurtenance" monitoring action level of 0.05 ppmv. The only trigger level for gas extraction and treatment based on appurtenance monitoring is the NIOSH IDLH of 50 ppmv.

The stand pipe monitoring (and also source gas extraction monitoring derived from back-calculated GES/TMP data) action levels are 2,000 ppmv, 10,000 ppmv, and 20,000 ppmv. These concentration values appear to be empirically derived from the historical data by examining the change in phosphine concentration over time.

1.4 December 2012 – RCRA Pond Gas Monitoring Program, Section 3 of RCRA Pond Post-Closure Plan, Volume 1

This document formalizes the FMC Framework discussed in Section 1.3 above with some minor changes. The most obvious changes are:

- The appurtenance monitoring action level for starting gas extraction and treatment is reduced from 50 ppmv to 35 ppmv.

- The stand pipe monitoring action level for starting gas extraction and treatment is reduced from 20,000 ppmv to 14,000 ppmv.

The plan is complicated but essentially involves increasing or decreasing the appurtenance and stand pipe monitoring frequency based on measurements with the Draeger instrument (Pac III and its model successors) that either exceed or stay below the various action levels. The guiding action level is a stand pipe action phosphine concentration below 2,000 ppmv. If the phosphine concentration in the stand pipe is less than 2,000 ppmv at any pond for 4 consecutive quarters, all monitoring is reduced to semiannual. If two consecutive semi-annual results are less than 2,000 ppmv, all monitoring is reduced to annual. If two consecutive annual results are less than 2,000 ppmv, all monitoring is discontinued. Likewise monitoring frequency increases up to monthly as other action levels are exceeded (e.g. 2,000 ppmv, 10,000 ppmv).

1.5 December 2012 – Appendix A to RCRA Pond Post-Closure Plan

This document provides additional details on the long-term post-closure monitoring plan including a Quality Assurance Project Plan and a Field Sampling Plan. Two confusing items from these plans which were identified from RME's review of the document are:

1. A footnote to the Table on page 9 of Appendix A-4 states with regard to monthly monitoring that when the stand pipe concentration equals or exceeds 14,000 ppmv; "GES units(s) operating data (average calculated source gas) and monitoring (if multiple standpipes without operating GES at one or more standpipes.)"

It is not clear what is meant by this footnote. Does this footnote mean that the average of the data collected from the monitoring event will be used? If there are multiple stand pipes, does this statement mean that the average of the data between the two stand pipes will be used?

2. A sentence on page 9 also states: Once routine perimeter pipe monitoring has been initiated due to a monitoring result of 2,000 ppmv or greater, the perimeter pipe monitoring program requires a minimum of 4 years of perimeter pipe monitoring and only if the subsequent perimeter pipe monitoring results are consistently below 2,000 ppmv.

Elsewhere in the plan it is stated that perimeter stand pipe monitoring will be discontinued after 2 years of results below 2,000 ppmv. Thus, it seems that in one place in the Plan 4 years of data are required, and in others only two years of data are required. This is fundamental discrepancy that should be investigated if this Plan is adopted for Post-Closure Monitoring.

1.6 Overall Review of Proposed Post-Closure Monitoring

The monitoring and gas extraction action levels appear to be generally based on: (1) the lower explosive limit for phosphine, (2) OSHA worker health and safety standards, and (3) empirical source concentration data FMC believes will provide adequate warning that concentrations are increasing to the point where the source gas concentration may eventually reach the lower explosive limit, or ambient air concentrations at the site may at some point exceed OSHA worker health and safety standards.

1.6.1 Health-Based Action Levels

Action levels designed to protect offsite industrial and residential receptors were not considered, or if they were, were not described in the documents reviewed by RME. Additionally, action levels designed to protect environmental receptors were likewise not discussed in any of the documentation reviewed by RME.

USEPA Region 10 has provided risk-based ambient air screening concentration levels protective for phosphine exposure of:

- 1.3 ug/m^3 (0.001 ppmv at average site temperature and pressure) for a Hazard Quotient equal to 1
- 0.31 ug/m^3 (0.0002 ppmv at average site temperature and pressure) for a Hazard Quotient equal to 1

These protective ambient air screening concentrations are well below the detection limit (0.02 ppmv) of the current monitoring instrumentation (i.e. the Draeger Pac III and its model successors).

Ecological benchmark values have not yet been provided by USEPA Region 10 and none were identified from a brief literature review of common sources for these values. A review of the Hazardous Substances Data Bank (HSDB) maintained by the U.S. National Library of Medicine revealed two studies on the chronic exposure of cats, guinea-pigs, and rats to phosphine. These two studies reported concentrations of 1.4 mg/m^3 (1.15 ppmv), 3.5 mg/m^3 (2.80 ppmv), and 3 ppmv as concentrations to which these mammals were exposed without any adverse effects. Although an ecological toxicologists should further review the available literature to determine a risk-based screening air concentration, assuming a safety factor of 100 on the above concentrations results in ecological protective benchmark concentrations in the same value range as the human health based air screening concentrations for phosphine.

Other published phosphine sampling and analysis methods were researched. The alternative phosphine analytical methods that were identified along with their detection limits include:

- NIOSH 6002 (100 ug/m^3)
- OSHA 1003 (45 ug/m^3)
- OSHA ID 180 (11 ug/m^3)
- CARB (8 ug/m^3)

- Modified NIOSH (5 ug/m^3)

Neither the FMC preferred monitoring method (Draeger Pac III), nor the alternative methods, are capable of measuring phosphine in ambient air at concentrations in the range of the health based screening level concentrations. Thus, an approach different than measuring phosphine in ambient air is needed to demonstrate that fugitive phosphine emissions from the ponds do not present a risk to human health and the environment.

2.0 GENERAL APPROACH

The purpose of the post-closure phosphine monitoring is to determine if phosphine is being released from the closed ponds at rates that may present a risk to human health and the environment, both on and offsite, and if so, trigger certain response actions including gas extraction and treatment. It is not possible to measure phosphine concentrations in the ambient air at EPA derived health based action levels applicable to offsite industrial and residential receptors.

Therefore, the goal of this analysis is to determine phosphine gas action levels based on human health and the environment that can be measured in the pond subsurface where phosphine gas concentrations have been shown to be present in the range that can be measured by one of the various methods. These measurements could be made inside the waste mass via the TMP wells in conjunction with the GES extraction equipment.

The approach considered uses the health based action levels for phosphine as recommended by USEPA Region 10 in conjunction with air dispersion modeling to determine an acceptable phosphine flux rate from the most likely emitting surface of the RCRA ponds. The flux rate was determined by using trial and error until the downwind concentration at the most impacted receptor reached a value of just below the health based action level. This flux rate was then used to determine the concentration in the air space 1 to 2 inches above the emitting surface. This surface air concentration was then extrapolated to a soil gas concentration at a depth of 18 to 24 inches below the emitting surface based on some of the monitoring data collected to date. The surface soil gas concentration was then extrapolated to the pore space concentration under the RCRA ponds based on the monitoring data reported in the Phosphine Assessment Study Report.

3.0 AIR DISPERSON MODELING

The American Meteorological Society/EPA Regulatory Model (AERMOD, Version 14134) was used to trial and error phosphine flux rates from the emitting surface of the RCRA ponds until the 8-hr average air concentration at the closest offsite industrial receptor equaled a concentration of approximately 1.3 ug/m^3, the U.S. EPA Region 10 phosphine air screening concentration for industrial exposures. Residential receptor locations were also considered at the recommended annual average air screening concentration of 0.31 ug/m^3; but the industrial location was found to the control the analysis due to the distance of the residential receptor locations from the pond source areas. The AERMOD interface developed by Lakes Environmental (Version 8.8.9) was used to facilitate model set-up.

The majority of the modeling used the low wind speed beta option in the non-regulatory control commands because it was expected that the highest downwind concentrations would occur at lower wind speeds. However, for the year with highest impacts AERMOD was also run with the low wind speed option turned off to provide a basis of comparison. [In some cases, regulatory required dispersion modeling (e.g. PSD modeling) does not allow the use of the beta low wind speed option.]

3.1 Emitting Surface

The emitting surface (i.e. the surface area over which phosphine gas is emitted) was modeled as an AERMOD area source with a surface area equivalent to an area 10 feet wide by the lengths of the 4 sides of the ponds. This is the surface area over which surface monitoring is currently being performed depending on the various trigger levels in the approved air monitoring program. As stated in the plans and suggested by the soil gas step-out monitoring performed to date, this surface area is located just beyond the cap liner anchor trench and is the location where the greatest emissions are expected to occur. A separate model run was also completed for the year of meteorological data with the greatest impacts assuming a 30 foot emitting surface width for the purposes of comparison. (See Charts 1 and 2 below).

The study was limited to ponds 15S, 16S, 17, and 18A because previous studies have demonstrated that phosphine is being emitted at much lower concentrations in the other RCRA ponds.

Chart 1: Determination of Area Source Length and Width based on 10' Width of Emitting Surface

POND	LENGTH (ft)[1]	WIDTH (ft)	SA (m2)	LENGTH/WIDTH AREA SOURCE TERM (m)
15S	3080	10	2,861	53.5
16S	2850	10	2,647	51.5
17	2300	10	2,137	46.2
18A	2250	10	2,090	45.7

Notes:

1. From RCRA Pond QAPP for Gas Monitoring, p. 10, December 2012. Value checked for reasonableness by scaling from Google Earth.

Chart 2: Determination of Area Source Length and Width based on 30' Width of Emitting Surface

POND	LENGTH (ft)[1]	WIDTH (ft)	SA (m2)	LENGTH/WIDTH AREA SOURCE TERM (m)
15S	3080	30	8,583	92.6
16S	2850	30	7,942	89.1
17	2300	30	6,410	80.1
18A	2250	30	6,270	79.2

Notes:

1. From RCRA Pond QAPP for Gas Monitoring, p. 10, December 2012. Value checked for reasonableness by scaling from Google Earth.

The length and width of the area source term was taken as the square root of the calculated surface area and centered on each pond. An area source term 10' wide by the length of the pond sides (the actual geometry of the emitting surface) was not used due to the AERMOD User's Guide recommendation to limit the length to width aspect ratio of an area source to less than 10 to 1. A diagram of the modeled sources is as follows.

Diagram 1: Overview of Modeled Sources

3.2 Meteorological Data

RME obtained five years of meteorological data to conduct this analysis. The data consisted of TD-3505 surface data from the Pocatello Municipal Airport (Station 24156) with upper air data from the Boise Airport (Station 24131) for the years 2009 through 2013.

The data were processed via Lakes Environmental' s AERMET View version 8.8.9 which implements EPA's AERMET_14134 meteorological pre-processing program. AERMET was set to use AERMINUTE data, adjust the friction velocity, and set a minimum wind speed threshold of 0.5 meters/sec. Annual average Albedo, Bowen Ratio, and Surface Roughness were derived from EPA's AERSURFACE program, which was implemented for twelve directional sectors based on the U.S. Geological Survey National Land Cover Data (NLCD) for 1992. The five years of meteorological data were combined to prepare a single five year meteorological data set that was used for the modeling.

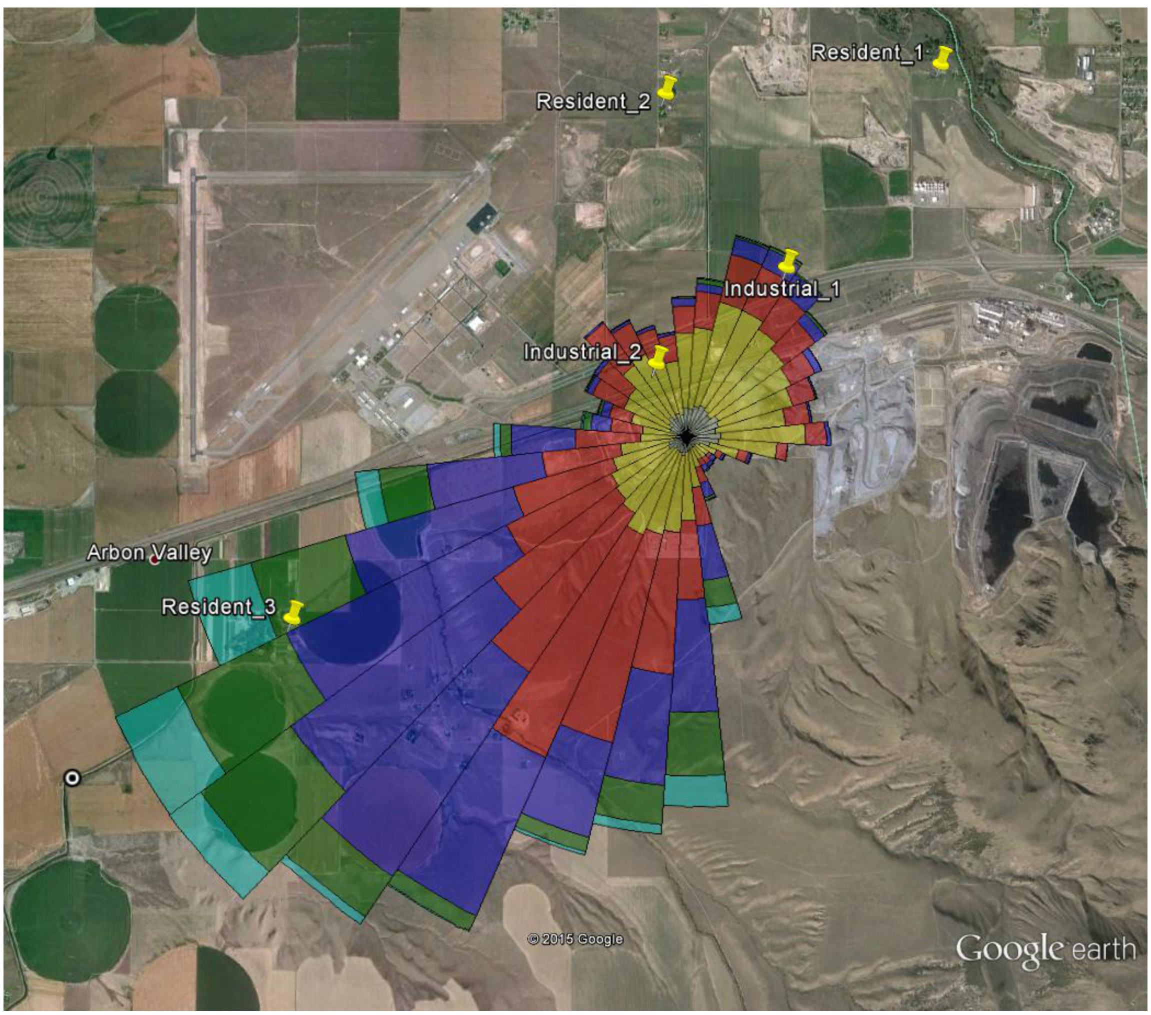

Diagram 2: Wind Rose (Blowing From) for Wind Direction and Speed (2009 – 2013)

3.3 Receptors

A total of five receptors were evaluated in this initial analysis. Three of the receptors evaluated are located at the nearest residential locations based on site reconnaissance and aerial photograph review. The remaining two receptors reflect potential future industrial use locations that both currently display characteristics of agricultural land use. Industrial_1 is reflective of SRIA Parcel 4 under the USEPA Ready for Re-Use Determination dated October 25, 2010. Industrial_2 is a location that RME understands is not owned or operated by FMC, but is located immediately west of SRIA Parcel 1 and the former TESCO property, which are also discussed in the USEPA Ready for Re-use Determination. A diagram of the receptor locations with respect to the modeled source areas is shown in the following diagram. The receptors were assigned a flagpole receptor height of 1.5 meters (4.9 feet) to approximate the height of the breathing zone of offsite industrial workers.

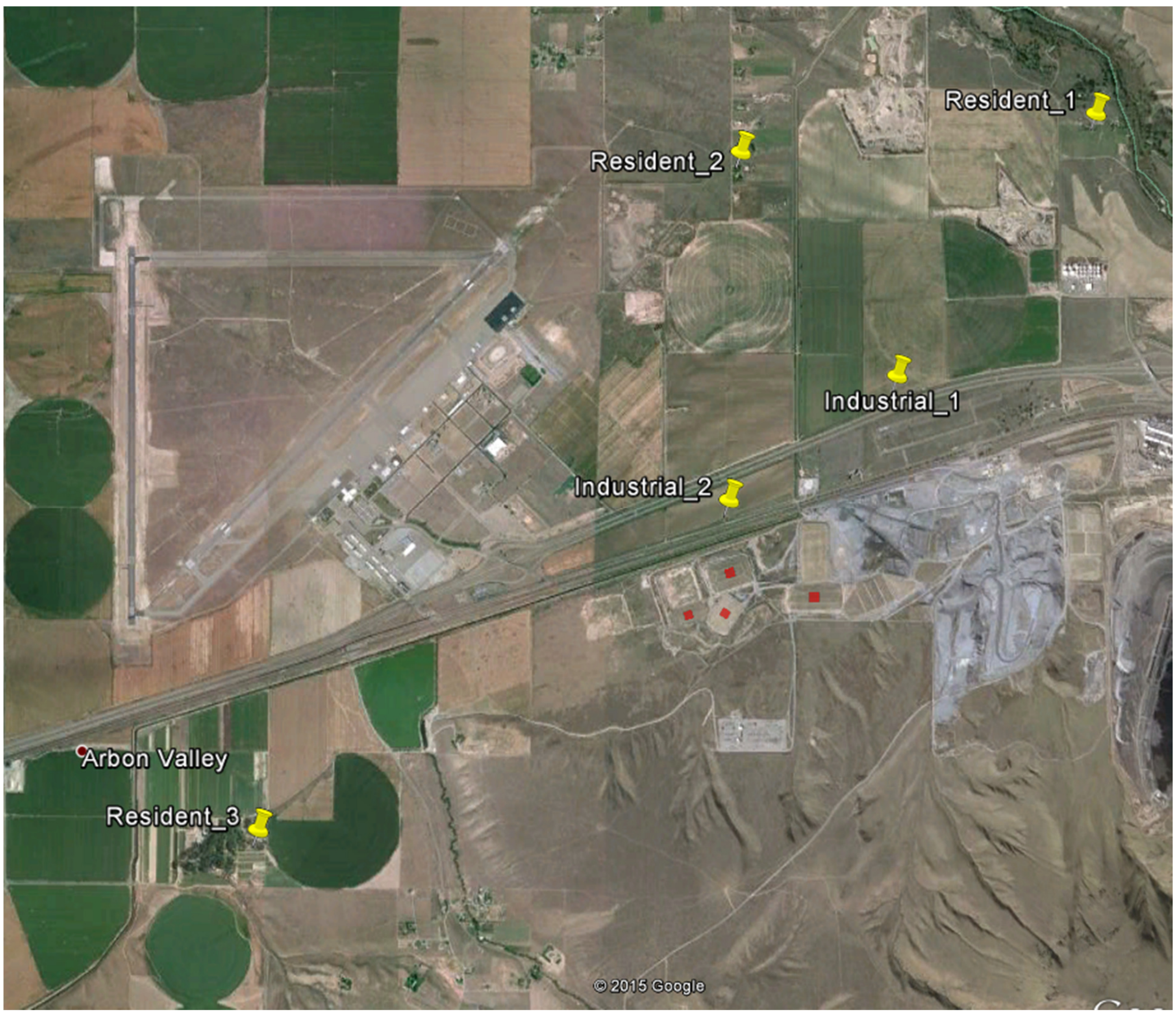

Diagram 3: Receptor Locations Evaluated in Modeling

3.4 Terrain Data

RME used the AERMAP program (Version 11103) embedded into Lakes Environmental AERMOD View version 8.8.9. NASA Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) 30 meter terrain data were downloaded from www.webgis.com and processed via AERMAP. This terrain data was selected because it is more recent (i.e. developed in the year 2000) than terrain data that was developed from older USGS maps. An overview of the terrain surrounding the Facility is shown below.

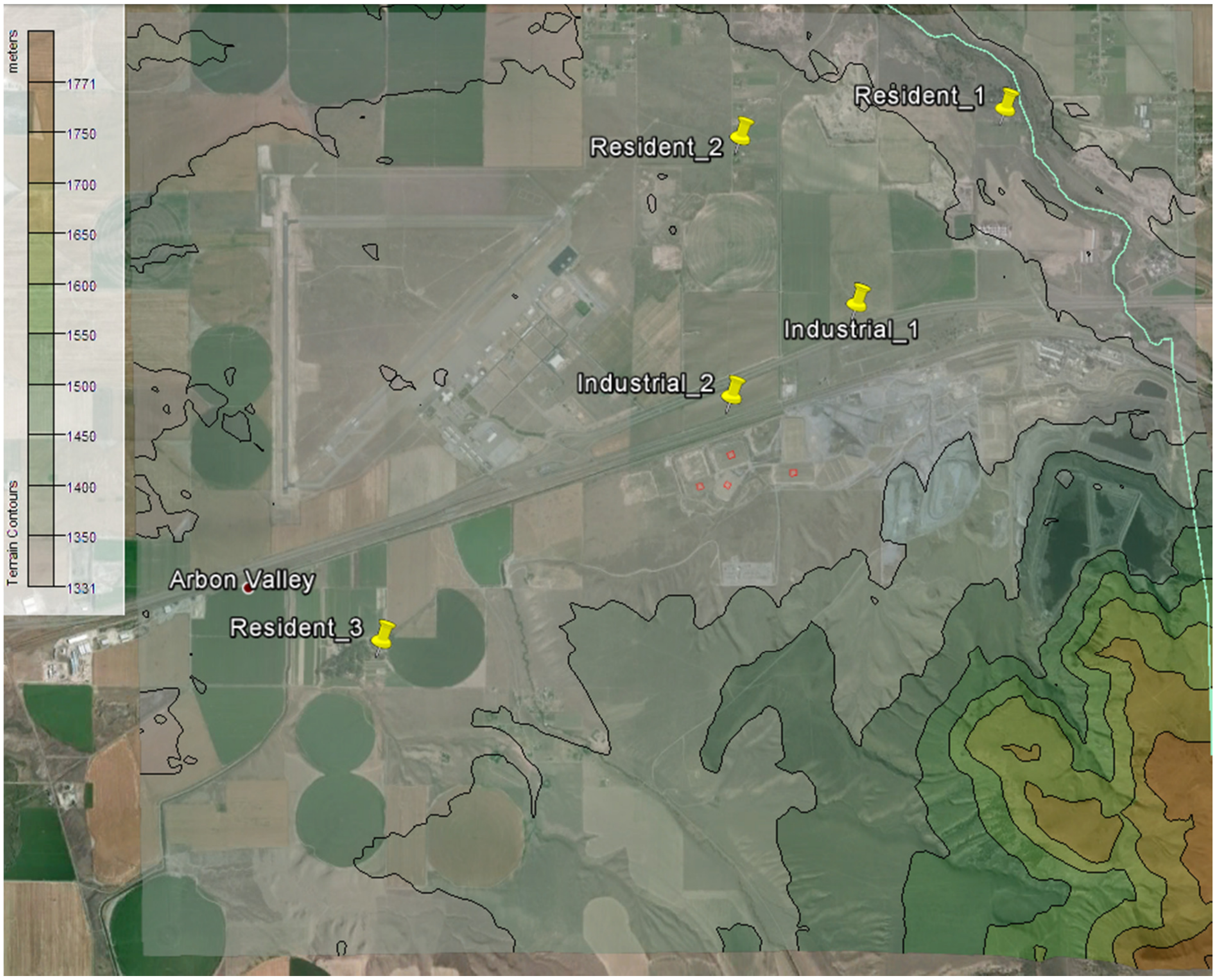

Diagram 4: Terrain Inside Modeling Domain

4.0 MODELING RESULTS

The air dispersion modeling results are summarized below.

Chart 3: Summary of Air Dispersion Modeling Results

MODEL YEAR	WIDTH OF EMITTING SURFACE (ft)	RECEPTOR HEIGHT ABOVE GROUND (ft)	PHOSPHINE FLUX RATE (g/m2-sec)	MODELED CONCENTRATION (ug/m3, First High Annual Average for Residents, First High 8-hr Average for Industrial)				
				Resident 1	Resident 2	Resident 3	Industrial 1	Industrial 2
2009	10	4.9	1.20E-06	0.0027	0.0031	0.0031	0.2096	1.1109
2010	10	4.9	1.20E-06	0.0020	0.0026	0.0030	0.1696	1.1197
2011	10	4.9	1.20E-06	0.0028	0.0031	0.0032	0.1786	0.8276
2012	10	4.9	1.20E-06	0.0032	0.0034	0.0029	0.1904	0.7478
2013	10	4.9	1.20E-06	0.0026	0.0029	0.0033	0.1691	1.2952
2013	10	0	1.20E-06	0.0026	0.0029	0.0033	0.1686	1.2777
2013	30	4.9	4.57E-07	0.0030	0.0033	0.0037	0.1929	1.2976

Inspection of the data in Chart 3 above shows that the first high annual average phosphine concentrations at the residential receptor locations for all years of meteorological data are well below the health based concentration screening level of 0.31 ug/m^3 when the flux rates described in the table are used as an input parameter. The 2013 first high 8-hr average air concentration at the Industrial 2 receptor location is just below the 1.3 ug/m^3 air screening concentration for industrial exposures when the flux rates described in the table are used as an input parameter. The meteorological data from the year 2013 result in the highest first high 8-hour average ambient air concentrations. The first high 8-hr average phosphine concentrations for meteorological data years 2009 – 2012 are less than the 2013 value.

Thus, the phosphine flux rates of 1.2E-6 g/m2-sec for a 10'wide emitting surface and 4.47E-7 g/m2-sec flux rate for 30' wide emitting surface were carried forward in the analysis.

5.0 DETERMINATION OF PHOSPHINE SURFACE AIR CONCENTRATION

The volume of phosphine gas in the 1 to 2 inch layer above a unit area of the emitting surface was then calculated based on the flux rate determined from the air dispersion modeling and the ideal gas law as summarized in the Chart below.

Chart 4: Determination of Volume of Phosphine Gas in Emitting Surface Layer

EMITTING SURFACE AREA	FLUX-RATE (g/m2-sec)[1]	UNIT SA (m2)[2]	MASS RATE (g/sec)[3]	MOLES/SEC[4]	TEMP (K)[5]	PRESS (mmHg)[6]	R (m3 mmHg / K-gmol)	PH3 GAS VOLUME (m3/sec)[7]
Pond Length * 10 ft Width	1.20E-06	1	1.20E-06	3.53E-08	281.51	647.8	6.24E-02	9.57E-10
Pond Length * 30 ft Width	4.57E-07	1	4.57E-07	1.34E-08	281.51	647.8	6.24E-02	3.64E-10

Notes:

1. Modeled phosphine flux rate from Chart 3 based on offsite health based action levels.
2. Unit surface area of the emitting surface.
3. Calculated as: Flux Rate * Surface Area.
4. Calculated as: Mass Rate (g/sec) * gmol/33.99758 g.
5. Average temperature from the five years of meteorological data considered in the air dispersion modeling.
6. Average atmospheric pressure from the five years of meteorological data considered in the air dispersion modeling.
7. Calculated as: V = nRT/P.

The concentration of phosphine gas in the monitored surface layer (1 to 2 inches above the ground surface) was then determined by calculating the volume of gas in a unit layer of 1 square meter above the ground surface and dividing this volume by the volume of phosphine gas emitted every second assuming the ponds are emitting at the flux rate determined from the modeling. This calculation assumes that the wind removes the contaminated air from the emitting surface every second so that surface layer is continuously replace with new phosphine gas. The calculation process is summarized in the Chart below.

Chart 5: Determination of PH3 Gas Concentration in Air Above Emitting Surface Based on Modeled Flux Rate

EMITTING SURFACE AREA	HEIGHT ABOVE SURFACE (in)	VOLUME OF GAS IN THIS LAYER (m3) WITH 1 m2 SA[1]	VOLUME OF PH3 GAS IN SURFACE LAYER EVERY SECOND (m3)[2]	CONC OF PH3 GAS IN SURFACE LAYER (ppmv)[3]	DETECTION LIMIT OF DRAEGER PAC III with XXS PH3 SENSOR (ppmv)[4]
Pond Length * 10 ft Width	1	0.025	9.57E-10	0.04	0.02
	2	0.051	9.57E-10	0.02	
Pond Length * 30 ft Width	1	0.025	3.64E-10	0.01	
	2	0.051	3.64E-10	0.007	

Notes:

1. Calculated as: Depth (in) * ft/12 in * m/3.281 ft * 1 m2.
2. From Chart 4.
3. Vol PH3/Total Volume * 1E6.
4. From the "DragerSensor & Portable Instruments Handbook", p. 178.

6.0 DETERMINATION OF PHOSPHINE ACTION LEVELS IN THE WASTE MASS

The determination of phosphine action levels in the waste mass that could result in flux rates that may be of risk to human health and the environment is based on the use of dilution factors. That is, the phosphine gas that is generated within the waste mass is diluted or bound to the soil as it migrates from the waste mass to the shallow subsurface. The gas is further diluted or reduced in concentration as it moves from the shallow subsurface to the emitting surface. Working backward from the pond surface the analysis takes the following form:

$$C_{ss} = C_s \div DF_s$$

Where:

C_{ss} = Concentration of Phosphine Gas in the Shallow Subsurface
C_s = Concentration of Phosphine Gas at the Emitting Surface
DF_s = Dilution Factor between Css and Cs

And,

$$C_w = C_{ss} \div DF_{ss}$$

Where:

C_w = Concentration of Phosphine Gas in the Waste
C_{ss} = Concentration of Phosphine Gas in the Shallow Subsurface
DF_{ss} = Dilution Factor between Css and Cw

The RCRA Phosphine Study Report (see Section 1.2 above) describes sampling and analysis of phosphine gas concentrations in the waste mass, in the shallow subsurface, and at the emitting surface of the RCRA ponds. Some of the data reported in this study was used to derive the dilution factors described in the equations above. Some other data was derived from the GES spreadsheets for certain days (Days 3/3/2011, 12/13/2011, 12/19/2011, and 12/27/2011).

The data used to calculate the dilution factors was limited to days where measurements of the phosphine air concentrations in the waste mass and the shallow soil overlapped with respect to the time period when the data were collected. The data were also limited to exclude time periods when: (1) the atmospheric pressure was rising (with the exception of time periods at the start of an incline after a steep decline in pressure), (2) the atmospheric pressure had recently peaked, or (3) when the atmospheric pressure was highly variable and did not display an overall trend of decreasing pressure. Previous analyses submitted by FMC confirm that phosphine emissions are somewhat dependent on atmospheric pressure and generally occur when atmospheric pressure is falling. The soil gas survey data in the Phosphine Assessment Study generally confirm this trend with higher soil gas concentrations occurring when the atmospheric pressure is falling. The calculation of the Dilution Factors is shown in Charts 6 and 7 below. Data from Pond 17 were not used because the shallow soil gas concentration data exceeded the detection limit in a rare number of instances and even then only slightly. Given the overall uncertainty of this analysis it was determined that use of the Pond 17 data would only add additional uncertainty.

One significant source of uncertainty in this analysis is the lack of extensive phosphine surface concentration data. Not only does the instrument used to measure surface concentrations have a relatively high detection limit with respect to the health based action levels (see Chart 5), but the data are not collected on a frequent basis. There was no detection of phosphine at the pond surface during the time periods of the waste concentration and shallow soil gas data, or no monitoring was conducted at that time. Thus, the manufacturer reported detection limit for the Draeger Pac III (0.02 ppmv) was used to represent the phosphine surface concentrations. In an effort to examine the uncertainty associated with using a detection limit of 0.02 ppmv, a surface concentration value of 0.009 ppmv was also examined. This value was selected to represent the FMC reported detection limit of the Draeger Pac III instrument (0.00 ppmv).

The Dilution Factors calculated in in Charts 6 and 7 were then used to calculate a phosphine gas concentration in the waste mass based on the health based surface gas concentration action levels derived from the air dispersion modeling (see Chart 5.) Chart 5 provides four different concentrations depending on the assumed depth of the surface layer and the size of the emitting surface. Each of these concentration was carried forward in the analysis to help address the overall uncertainty of the analysis. The calculations are summarized in Charts 9 and 10.

Chart 6: Calculation of Dilution Factors Based on Phosphine Surface Concentration of 0.02 ppmv

POND	DATE[1]	AVG. C_w CONC. (ppmv)[2]	AVG. C_{ss} CONC. (ppmv)[3]	AVG. C_s CONC. (ppmv)[4]	DFss[5]	DFs[6]	TIME PERIOD OF MEASUREMENT WITH RESPECT TO CHANGES IN ATMOSPHERIC PRESSURE[7]
15S	2/17/2011	96,088	149	0.02	1.56E-03	1.34E-04	End of long decline, start of climb.
15S	3/8/2011	77,540	22.2	0.02	2.86E-04	9.02E-04	Start of climb after steep decline.
15S	12/8/2011	51,328	29.1	0.02	5.68E-04	6.86E-04	Bottom of slight trough after even period.
15S	12/13/2011	111,332	64.7	0.02	5.81E-04	3.09E-04	Trough after decline.
15S	12/19/2011	122,338	63.5	0.02	5.19E-04	3.15E-04	Trough after decline.
15S	12/27/2011	133,126	122	0.02	9.18E-04	1.64E-04	Middle of long decline.
15S	1/5/2012	67,526	103	0.02	1.52E-03	1.94E-04	Middle of decline.
				Average	**8.50E-04**	**3.86E-04**	
16S	3/2/2011	1,059	0.069	0.02	6.52E-05	2.90E-01	Trough of decline.
16S	10/5/2011	3,660	0.861	0.02	2.35E-04	2.32E-02	Middle of decline that began in September.
16S	12/8/2011	5,238	0.156	0.02	2.98E-05	1.28E-01	Bottom of slight trough after even period.
16S	1/4/2012	7,193	0.398	0.02	5.53E-05	5.03E-02	Trough of minor decline.
				Average	**9.64E-05**	**1.23E-01**	
18A	3/3/2011	8,997	101	0.02	1.12E-02	1.98E-04	Trough of decline.

Notes:

1. Date selected based on dates with TMP Waste Concentration data overlapping soil gas survey data.
2. Average of TMP measurements from Phosphine Study Report, Final Update; except dates 12/13/2011, 12/19/2011, and 12/27/2011 for Pond 15S which are based on GES spreadsheet data for TMP02.
3. Average of Soil Gas Survey data from Phosphine Study Report for each probe using detection limit when reported value was zero.
4. Based on detection limit of Draeger Pac III instrument and review of available data which indicates that phosphine was not detected at the surface during the time frame of the TMP and soil gas survey data.
5. Calculated as: Css/Cw.
6. Calculated as: Cs/Css.
7. Based on examination of atmospheric pressure data from the meteorological data set used in the air dispersion modeling.

Chart 7: Calculation of Dilution Factors Based on Phosphine Surface Concentration of 0.009 ppmv

POND	DATE[1]	AVG. C_w CONC. (ppmv)[2]	AVG. C_{ss} CONC. (ppmv)[3]	AVG. C_s CONC. (ppmv)[4]	DFss[5]	DFs[6]	TIME PERIOD OF MEASUREMENT WITH RESPECT TO CHANGES IN ATMOSPHERIC PRESSURE[7]
15S	2/17/2011	96,088	149	0.009	1.56E-03	6.02E-05	End of long decline, start of climb.
15S	3/8/2011	77,540	22.2	0.009	2.86E-04	4.06E-04	Start of climb after steep decline.
15S	12/8/2011	51,328	29.1	0.009	5.68E-04	3.09E-04	Bottom of slight trough after even period.
15S	12/13/2011	111,332	64.7	0.009	5.81E-04	1.39E-04	Trough after decline.
15S	12/19/2011	122,338	63.5	0.009	5.19E-04	1.42E-04	Trough after decline.
15S	12/27/2011	133,126	122	0.009	9.18E-04	7.36E-05	Middle of long decline.
15S	1/5/2012	67,526	103	0.009	1.52E-03	8.75E-05	Middle of decline.
				Average	**8.50E-04**	**1.74E-04**	
16S	3/2/2011	1,059	0.069	0.009	6.52E-05	1.30E-01	Trough of decline.
16S	10/5/2011	3,660	0.861	0.009	2.35E-04	1.05E-02	Middle of decline that began in September.
16S	12/8/2011	5,238	0.156	0.009	2.98E-05	5.77E-02	Bottom of slight trough after even period.
16S	1/4/2012	7,193	0.398	0.009	5.53E-05	2.26E-02	Trough of minor decline.
				Average	**9.64E-05**	**5.53E-02**	
18A	3/3/2011	8,997	101	0.009	1.12E-02	8.91E-05	Trough of decline.

Notes:

1. Date selected based on dates with TMP Waste Concentration data overlapping soil gas survey data.
2. Average of TMP measurements from Phosphine Study Report, Final Update; except dates 12/13/2011, 12/19/2011, and 12/27/2011 for Pond 15S which are based on GES spreadsheet data for TMP02.
3. Average of Soil Gas Survey data from Phosphine Study Report for each probe using detection limit when reported value was zero.
4. Based on detection limit of Draeger Pac III instrument and review of available data which indicates that phosphine was not detected at the surface during the time frame of the TMP and soil gas survey data.
5. Calculated as: Css/Cw.
6. Calculated as: Cs/Css.
7. Based on examination of atmospheric pressure data from the meteorological data set used in the air dispersion modeling.

Chart 8: Waste Mass Action Levels Determined from Health Based Concentrations, Air Dispersion Modeling, and Surface Air Concentration Detection Limit of 0.02 ppmv

TECHNIQUE[1]	SURFACE CONC. (Cs - ppmv)[2]	DFs[3]	SHALLOW SOIL GAS CONC. (Css - ppmv)[4]	DFss[5]	CONC. IN WASTE MASS (Cw-ppmv)[6]
Based on Pond 15S DFs	0.04	3.86E-04	98	8.50E-04	114,680
Based on Pond 16S DFs	0.04	1.23E-01	0.31	9.64E-05	3,180
Based on Pond 18A DFs	0.04	1.98E-04	190	1.12E-02	16,942
				AVERAGE	**44,934**
Based on Pond 15S DFs	0.02	3.86E-04	49	8.50E-04	57,340
Based on Pond 16S DFs	0.02	1.23E-01	0.15	9.64E-05	1,590
Based on Pond 18A DFs	0.02	1.98E-04	95	1.12E-02	8,471
				AVERAGE	**22,467**
Based on Pond 15S DFs	0.01	3.86E-04	37	8.50E-04	43,674
Based on Pond 16S DFs	0.01	1.23E-01	0.12	9.64E-05	1,211
Based on Pond 18A DFs	0.01	1.98E-04	72	1.12E-02	6,452
				AVERAGE	**17,112**
Based on Pond 15S DFs	0.007	3.86E-04	19	8.50E-04	21,837
Based on Pond 16S DFs	0.007	1.23E-01	0.06	9.64E-05	606
Based on Pond 18A DFs	0.007	1.98E-04	36	1.12E-02	3,226
				AVERAGE	**8,556**
				AVERAGE OF THE AVERAGES	**23,267**

Notes:

1. Identifies with Dilution Factors are used to calculate the air concentration in the waste mass.
2. Range of surface air concentrations determined from air dispersion modeling; see Chart 5.
3. From Chart 6.
4. Calculated as: Surface Conc. / DFs.
5. From Chart 6.
6. Calculated as: Shallow Gas Conc. / DFss.

Chart 9: Waste Mass Action Levels Determined from Health Based Concentrations, Air Dispersion Modeling, and Surface Air Concentration Detection Limit of 0.009 ppmv

TECHNIQUE	SURFACE CONC. (Cs - ppmv)	DFs	SHALLOW SOIL GAS CONC. (Css - ppmv)	DFss	CONC. IN WASTE MASS (Cw-ppmv)
Based on Pond 15S DFs	0.04	1.74E-04	217	8.50E-04	254,843
Based on Pond 16S DFs	0.04	5.53E-02	0.68	9.64E-05	7,067
Based on Pond 18A DFs	0.04	8.91E-05	423	1.12E-02	37,650
				AVERAGE	**99,853**
Based on Pond 15S DFs	0.02	1.74E-04	108	8.50E-04	127,422
Based on Pond 16S DFs	0.02	5.53E-02	0.34	9.64E-05	3,533
Based on Pond 18A DFs	0.02	8.91E-05	211	1.12E-02	18,825
				AVERAGE	**49,927**
Based on Pond 15S DFs	0.01	1.74E-04	83	8.50E-04	97,053
Based on Pond 16S DFs	0.01	5.53E-02	0.26	9.64E-05	2,691
Based on Pond 18A DFs	0.01	8.91E-05	161	1.12E-02	14,338
				AVERAGE	**38,027**
Based on Pond 15S DFs	0.007	1.74E-04	41	8.50E-04	48,526
Based on Pond 16S DFs	0.007	5.53E-02	0.13	9.64E-05	1,346
Based on Pond 18A DFs	0.007	8.91E-05	80	1.12E-02	7,169
				AVERAGE	**19,014**
				AVERAGE OF THE AVERAGES	**51,705**

Notes:

1. Identifies with Dilution Factors are used to calculate the air concentration in the waste mass.
2. Range of surface air concentrations determined from air dispersion modeling; see Chart 5.
3. From Chart 7.
4. Calculated as: Surface Conc. / DFs.
5. From Chart 7.
6. Calculated as: Shallow Gas Conc. / DFss.

7.0 ACTION LEVELS

Chart 8 provides a range of phosphine gas concentrations in the waste mass (measured at the TMPs) determined from air dispersion modeling and recommended health based action levels with the surface monitoring detection limit equal to 0.02 ppmv (the manufacturer reported detection limit for the Pac III monitoring instrument.) Chart 9 provides a range of phosphine gas concentrations in the waste mass (measured at the TMPs) determined from air dispersion modeling and recommended health based action levels with the surface monitoring detection limit equal to 0.009 ppmv (the FMC represented detection limit for the Pac III monitoring instrument.) These phosphine gas concentrations may be used to determine when phosphine gas extraction and treatment may be started and stopped assuming that the gas extraction system employed is capable of controlling the release of phosphine gas. These action levels may be summarized as follows:

Chart 10: Summary of Health Based Action Levels for Waste Mass

CHART	HIGH CONC. (ppmv)	LOW CONC. (ppmv)	AVERAGE (ppmv)
8	44,934	8,556	23,267
9	99,853	19,014	51,705

FMC has proposed a complicated post closure monitoring and action plan as described in Sections 1.3 through 1.5 of this technical memorandum. The FMC plan generally uses different action levels based on different and sometimes unidentified criterion to define the frequency of monitoring and the actions that will be taken if the action levels are exceeded. A somewhat what more simplified monitoring and action level scheme based on the data provided in this technical memorandum and the historical record is proposed in Chart 11.

The proposed monitoring and action approach has three essential elements. The existing surface monitoring is identified as Importance Level 3 because it has the most uncertainty of the three essential monitoring elements. It is the most uncertain because the available surface monitoring instrumentation does not have low enough detection limits to ensure that all health-based action levels can be addressed through the monitoring of the emitting pond surface and because emissions from the ponds are affected to some degree by barometric pressure and the actual surface area over which emissions are occurring, both of which can be changing with respect to time. Thus, while this monitoring method is the most direct with respect to protecting human health and the environment, it is the most uncertain. Further, by the time phosphine concentrations are detected at the pond surface it is too late to take actions that will quickly reduce the concentrations because the pore space between the waste mass and the pond surface has become contaminated with relatively high levels of phosphine gas.

The Level 2 appurtenance monitoring is important because it is used to protect the health and safety of onsite workers. The health and safety of onsite workers is regulated by standards published by the Occupational Health and Safety Administration (OSHA). Although these standards are significantly outdated, they are the law with respect to onsite worker personnel and they govern the protection of workers whose task it is to maintain the RCRA caps and perform the work required by the various governmental authorities that define the scope of work at the site.

The Level 1 waste mass monitoring is the most important because the available monitoring instrumentation can easily measure the concentrations indicative of the waste mass and because the concentrations in the waste mass drive, to a significant degree, the mass of phosphine gas that is available to travel through subsurface beneath the ponds and then be released to the environment at the surface beyond the pond cap anchor trench. If the phosphine gas is controlled at its source, it will not be able to migrate to the ambient environment and potentially impact the health of people beyond the site boundary.

The stand-pipe monitoring is a reasonably good idea, was proposed by FMC, and provides an added layer of protection to the 3 other basic monitoring plans described above. The stand pipe monitoring is a primary trigger in the currently proposed FMC monitoring scheme. However, as demonstrated by the events at Pond 15S where the perimeter pipe became compromised due to high phosphine gas concentrations, it is more of a reactionary monitoring tool than a prospective monitoring tool, as compared to monitoring the concentrations in the waste mass.

Chart 8: Proposed Post Closure Monitoring and Action Plan Based on Data Designed to Protect Human Health and the Environment

IMPORTANCE	TYPE OF MONITORING	MONITORING FREQUENCY	MONITORING TIME PERIOD	ACTION LEVEL RELEVANT TO MONITORING	BASIS OF ACTION LEVEL	ACTION REQUIRED IF ACTION LEVEL EXCEEDED
3	Surface	Annually	As long as the ponds exist with monitoring conducted during periods of falling barometric pressure that occur at least 48 hours prior to the time of the monitoring.	0.04 ppmv	Offsite Human Health and Onsite Environment	Exceedance of 0.04 ppmv requires that a Work Plan be submitted to address the cause of the exceedance within 15 days of the date of the exceedance.
2	Appurtenance -12 inches from appurtenance as described in historical monitoring plans	Semi-Annually	Until concentrations are less than OSHA standards for 5 consecutive years, retroactive for two years from the date of the Post Closure Permit.	0.3 ppmv	Onsite Worker	Exceedance of 0.3 ppmv requires that a Work Plan be submitted to address the cause of the exceedance within 15 days of the date of the exceedance.
1	Waste Mass (i.e. TMP)	Quarterly-Wells with Flow	Until Concentrations are less than 9,000 ppmv for 5 consecutive years, retroactive for two years from the date of the Post Closure Permit; annually thereafter for as long as the ponds exist.	9,000 ppmv	Offsite Human Health and Onsite Environment	Initiate gas extraction and treatment for at least one quarter or until concentration falls below 9,000 ppmv for 4 consecutive quarters.
Other	Perimeter Stand Pipe	Semi-Annually	Until Concentrations are less than 2,000 ppmv for 5 consecutive years, retroactive for two years from the date of the Post Closure Permit.	2,000 ppmv	FMC Proposed	Exceedance of 2,000 ppmv requires that a Work Plan be submitted to investigate the cause of the exceedance within 30 days of the date of the exceedance.

A value of 0.04 ppmv in Chart 11 is recommended as the action level for the surface monitoring because this concentration is a health based protective concentration based on the air dispersion modeling that can be easily measured using the existing sampling and analytical techniques. This monitoring technique is assigned an importance value of 3 because it is so rarely performed and because by the time phosphine emissions are detected above health based action levels at this location such emissions could have been occurring for a long period of time.

A value of 0.3 ppmv in Chart 11 is recommended as the action level for the appurtenance monitoring because this concentration is the OSHA Permissible Exposure Limit for phosphine. This monitoring technique is assigned an importance value of 2 because, although it provides protection to onsite workers, it does not provide protection for offsite receptors.

A value of 9,000 ppmv in Chart 11 is recommended as the action level for the waste mass concentration monitoring in the TMPs because this value is the most conservative of the waste mass concentration values developed from the air dispersion modeling. This monitoring technique is assigned an importance factor of 1 because it assures protection of human health offsite and the environment onsite.

8.0 REFERENCES

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